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HELICITY AMPLITUDES AND ELECTROMAGNETIC DECAYS OF STRANGE BARYON RESONANCES

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We present results for the helicity amplitudes of the lowest-lying hyperon resonances Y^*, computed within the framework of the Bonn constituent-quark model, which is based on the Bethe-Salpeter approach [1,2,3]. The seven parameters entering the model are fitted against the best known baryon masses [4]. Accordingly, the results for the helicity amplitudes are genuine predictions. Some hyperon resonances are seen to couple more strongly to a virtual photon with finite Q^2 than to a real photon. Other Y^*'s, such as the $S_{01}(1670)$ Λ resonance or the $S_{11}(1620)$ Σ resonance, have large electromagnetic decay widths and couple very strongly to real photons. The negatively-charged and neutral members of a Σ^* triplet may couple only moderately to the $\Sigma(1193)$, while the positively-charged member of the same Σ^* triplet displays a relatively large coupling to the $\Sigma^+(1193)$ state. This illustrates the necessity of investigating all isospin channels in order to obtain a complete picture of the hyperon spectrum.

1. Introduction

The implementation of the electromagnetic (EM) couplings to a hadron resonance in isobar models constitutes one of its major sources of uncertainty. This is particularly the case for models including hyperon resonances, for which little experimental information is available. These Y^*'s can play an important role in the background of kaon electroproduction processes, photo- and electroproduction of the elusive $\Theta(1540)$ resonance, and radiative kaon capture reactions. In this work, the Bonn constituent-quark (CQ) model, based on the Lorentz-covariant Bethe-Salpeter approach, is used to compute the electromagnetic helicity amplitudes (HA's) of the lowest-lying

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hyperon resonances. The results may be used in isobar models where a $\gamma^{(*)}YY^*$ coupling gets introduced.

2. Helicity Amplitudes in the Bethe-Salpeter Approach

The expression for the current matrix elements in the framework of the Bonn CQ model can be found in Refs. 1, 2, 3 and 5. In the rest frame of the incoming baryon resonance, the EM transition matrix element reads :

$$\langle\, \overline{P}\,|\, j^\mu \,|\, \overline{M}^* \,\rangle \simeq -3 \iint \frac{\mathrm{d}^4\left[\frac{1}{2}\left(p_1-p_2\right)\right]}{(2\pi)^4} \frac{\mathrm{d}^4\left[\frac{1}{3}\left(p_1+p_2-2p_3\right)\right]}{(2\pi)^4} \times\, \overline{\Gamma}^{\Lambda}_{\overline{P}}\, S^1_F(p_1)\otimes S^2_F(p_2)\otimes\left[S^3_F(p_3+q)\,\hat{q}\gamma^\mu S^3_F(p_3)\right]\,\Gamma^{\Lambda}_{\overline{M}^*}\,, \quad (1)$$

where Γ and $\overline{\Gamma}$ are the amputated BS amplitude and its adjoint of the incoming and outgoing baryon respectively, and S^i_F is the i'th CQ propagator. In the above matrix element, the operator $\hat{q}\gamma^\mu$ describes how the photon couples to a pointlike CQ with charge $\hat{q}$.

The electromagnetic properties of baryon resonances are usually presented in terms of helicity amplitudes, which are functions of the squared fourmomentum of the photon. The HA's are directly proportional to the current matrix element with the appropriate spin projections for incoming and outgoing hyperon :

$$A_{1/2}\,(B^*\to B) \;=\; \mathcal{D}\left\langle B,\overline{P},\frac{1}{2}\right| j^1(0)\,+\,i\,j^2(0)\left| B^*,\overline{P}^*,-\frac{1}{2}\right\rangle \quad, \quad (2a)$$

$$A_{3/2}\,(B^*\to B) \;=\; \mathcal{D}\left\langle B,\overline{P},-\frac{1}{2}\right| j^1(0)\,+\,i\,j^2(0)\left| B^*,\overline{P}^*,-\frac{3}{2}\right\rangle \quad, \quad (2b)$$

$$C_{1/2}\,(B^*\to B) \,=\, \mathcal{D}\left\langle B,\overline{P},\frac{1}{2}\right| j^0(0)\left| B^*,\overline{P}^*,\frac{1}{2}\right\rangle\,, \quad (2c)$$

with $\mathcal{D}=\sqrt{\frac{\pi\alpha}{2M(M^{*2}-M^2)}}$, where α is the fine-structure constant and M^* (M) the mass of the incoming (outgoing) hyperon.

3. Results and Conclusions

In Fig. 1 we present our predictions for the HA's of the lowest-lying spin $J=3/2$ Λ resonances, decaying to the $\Lambda(1116)$. One notices that the $A_{1/2}$ and $C_{1/2}$ of the lightest resonance with either parity show a maximum at finite Q^2. This feature also occurs in some of the other HA's we have

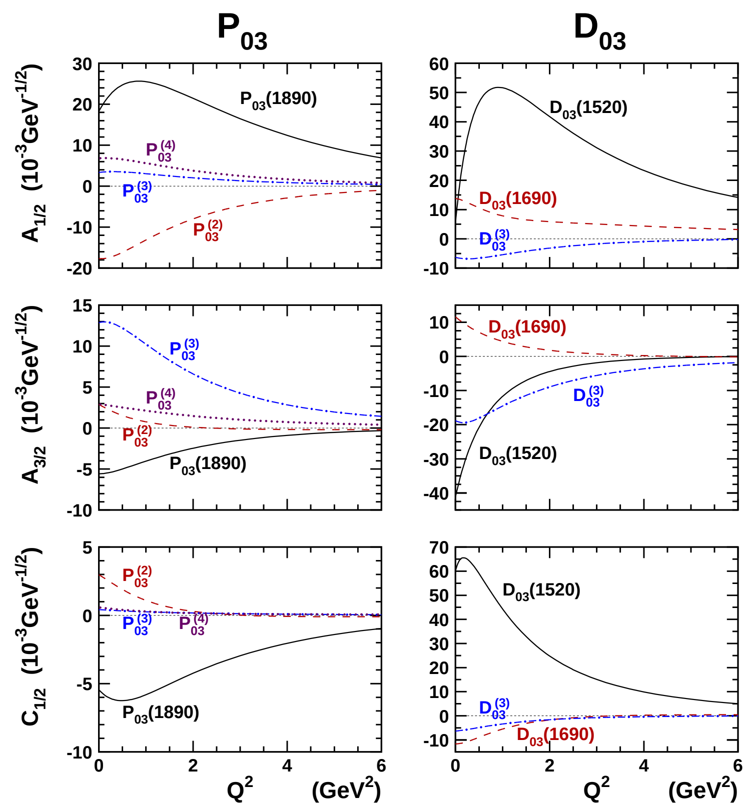

Figure 1. The Q^2 dependence for the $\Lambda^* + \gamma^* \to \Lambda$ decays for spin $J = 3/2$ resonances : left (right) panels show the results for the positive (negative) parity Λ^* resonances.

computed within the Bonn CQ model [3]. As a consequence, u-channel contributions to $p(e, e'K)Y$ processes, can be expected to exhibit a peculiar Q^2 dependence.

In Table 1, the EM decay widths of the hyperon resonances with masses around 1660 MeV are given. This is the energy region investigated by the Crystal Ball Collaboration in Brookhaven for the $\overline{K}^- p \to \gamma Y^0$ processes [6]. Our results indicate that the $S_{01}(1670)$ and $D_{03}(1690)$ Λ-resonances could be important if $Y^0 = \Sigma^0(1193)$. If on the other hand $Y^0 = \Lambda(1116)$, the $P_{11}(1660)$, $S_{11}(1620)$ and $D_{13}(1670)$ Σ-resonances seem to be more appropriate candidates for governing the reaction dynamics.

Another distinct feature illustrated by Table 1 is the dependence of

Table 1. Electromagnetic decay widths of the hyperon resonances around 1660 MeV to the different ground-state hyperons in units of MeV.

Y^*	$\Gamma_{Y^* \to \Lambda(1116)}$	$\Gamma_{Y^{*0} \to \Sigma^0(1193)}$	$\Gamma_{Y^{*+} \to \Sigma^+(1193)}$	$\Gamma_{Y^{*-} \to \Sigma^-(1116)}$
$S_{01}(1670)$	0.159×10^{-3}	3.827	—	—
$D_{03}(1690)$	0.0815	1.049	—	—
$P_{11}(1660)$	0.451	0.0578	0.733	0.141
$S_{11}(1620)$	1.551	0.688	5.955	0.613
$D_{13}(1670)$	1.457	0.0214	0.440	0.184

the EM decay widths of the Σ resonances on the isospin-3 component. For positively-charged Σ^*'s, the reported decay widths can be an order of magnitude larger than for the negatively-charged or neutral members of the isospin triplet. These resonances could therefore contribute to the background of the $p(\gamma, K^0)\Sigma^+$ process significantly, while being marginal for the $p(\gamma, K^+)\Sigma^0$ reaction.

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